



# HF & JetMET

S.Kunori

02-July-2004

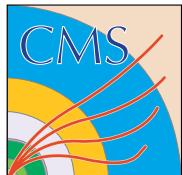


## Physics

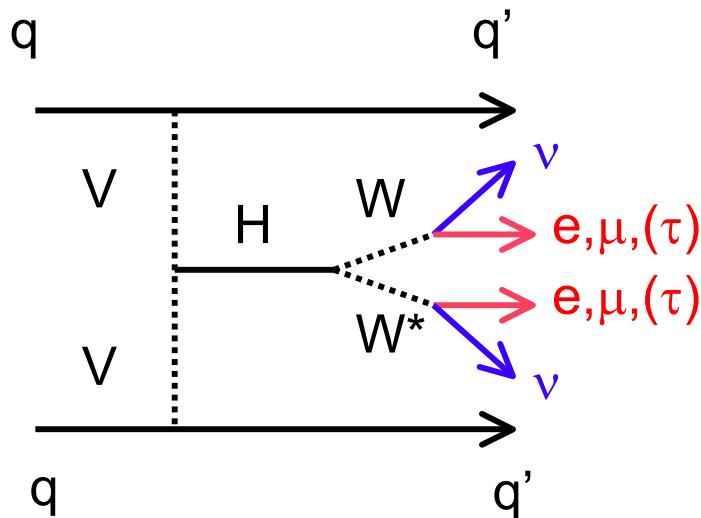
- **qqH** (eg.  $H \rightarrow WW \rightarrow l\nu l\nu$ ,  $H \rightarrow \tau\tau$ , ...)
  - Forward jet tagging
  - MET for Higgs mass reconstruction
- **SUSY**
  - MET + jets

## Issues

- **Calibration**
- **Dynamic range**



# qqH(120) $\rightarrow$ WW $\rightarrow$ l $\nu$ l $\nu$



## Signal

- two forward tagging jets
- no extra central jet
- two leptons  
soft lepton from  $W^*$  decay
- $M_T(WW)$

## Background

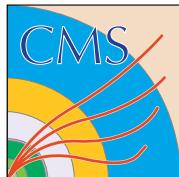
	Kauer et.al
tt $\rightarrow$ WbWb	2%
ttj $\rightarrow$ WbWb+j	50% (this analysis)
ttjj $\rightarrow$ WbWb +jj	11%
WWjj	25% (in progress)
$\tau\tau jj$	
lljj	

## Simulation

CompHEP+PYTHIA  
CMSIM(GEANT3)  
for  $2 \times 10^{33} \text{ cm}^{-2} \text{s}^{-1}$

**Result:  $\sim 70 \text{ fb}^{-1}$  for  $5\sigma$  signal**

(See CMS Note 2002/016 for more details)

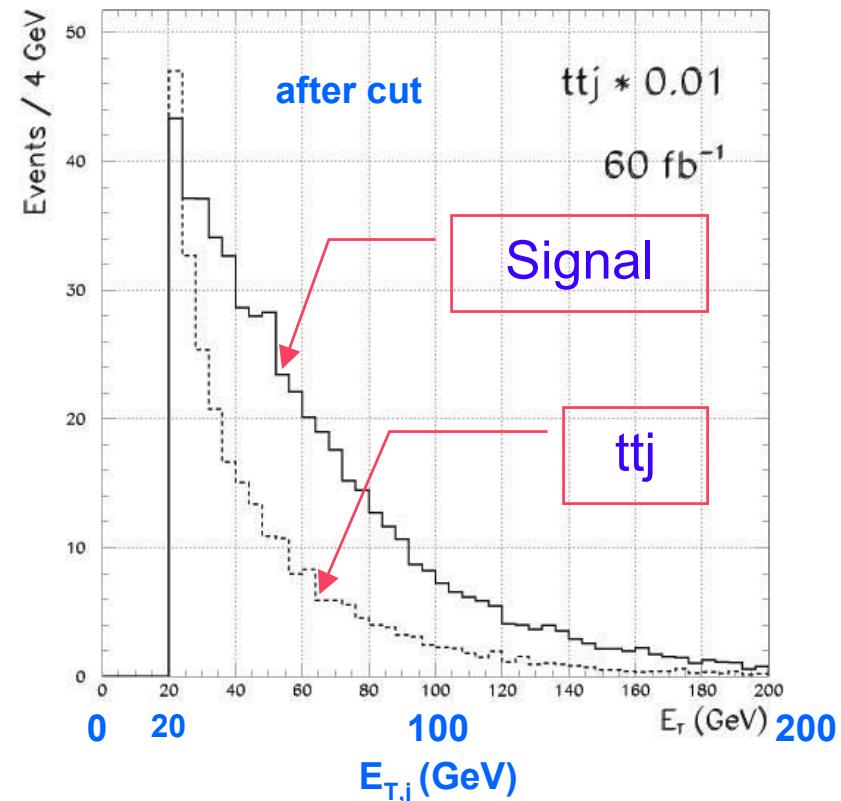
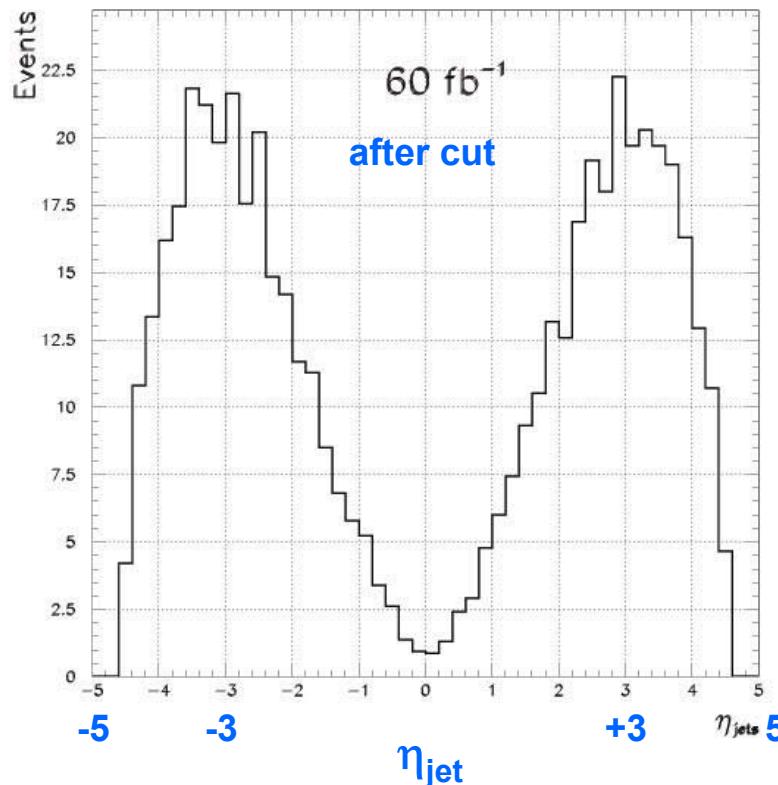
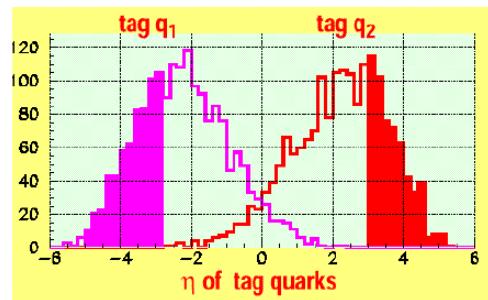


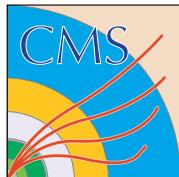
# Forward Tagging Jets

- after forward jet tagging selection -

Generated  
quarks

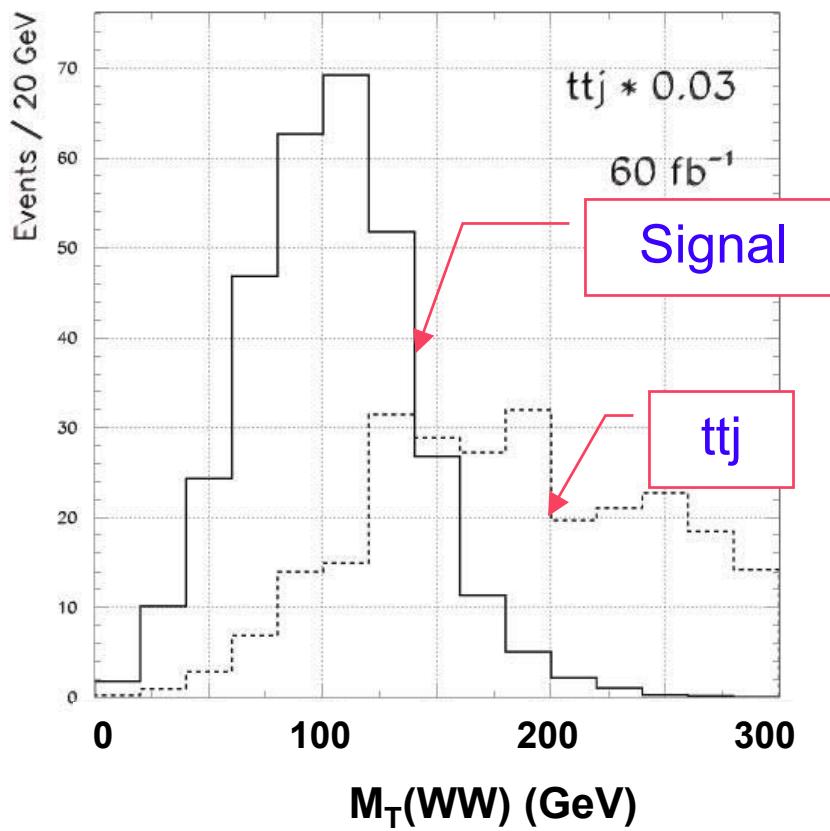
2q in HF 7%  
1q in HF 46%  
0q in HF 47%





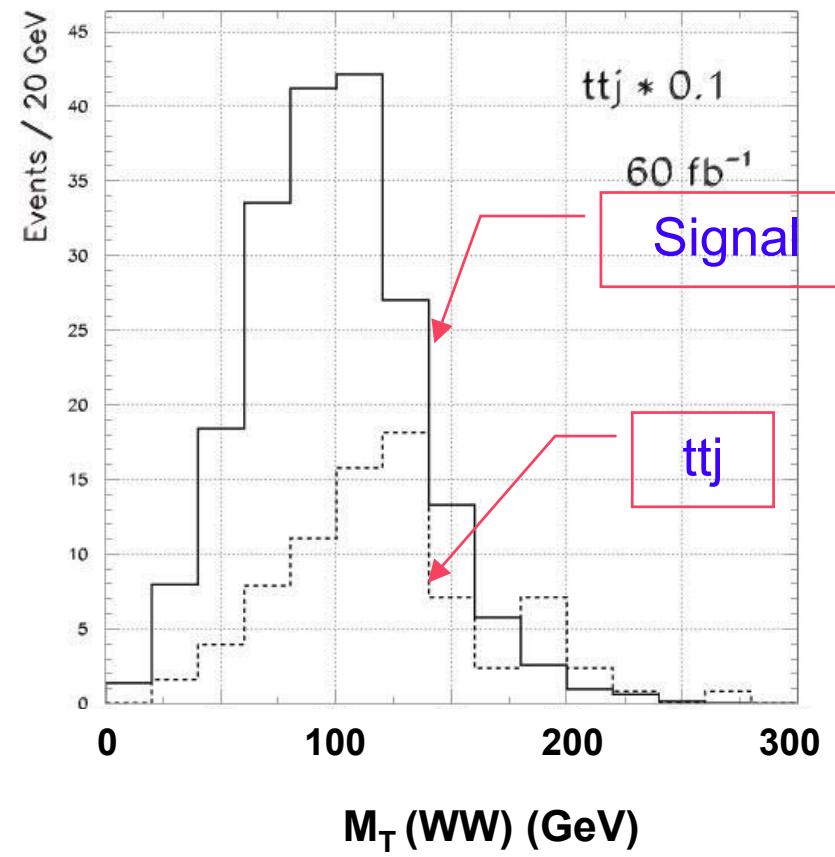
# Transverse Mass: $M_T(WW)$

Without Mass(II) and  $\phi(II)$  cuts

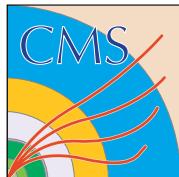


$$m_T(WW) = \sqrt{(E_T + E_{T, ll})^2 - (\vec{p}_T + \vec{p}_{T, ll})^2}$$

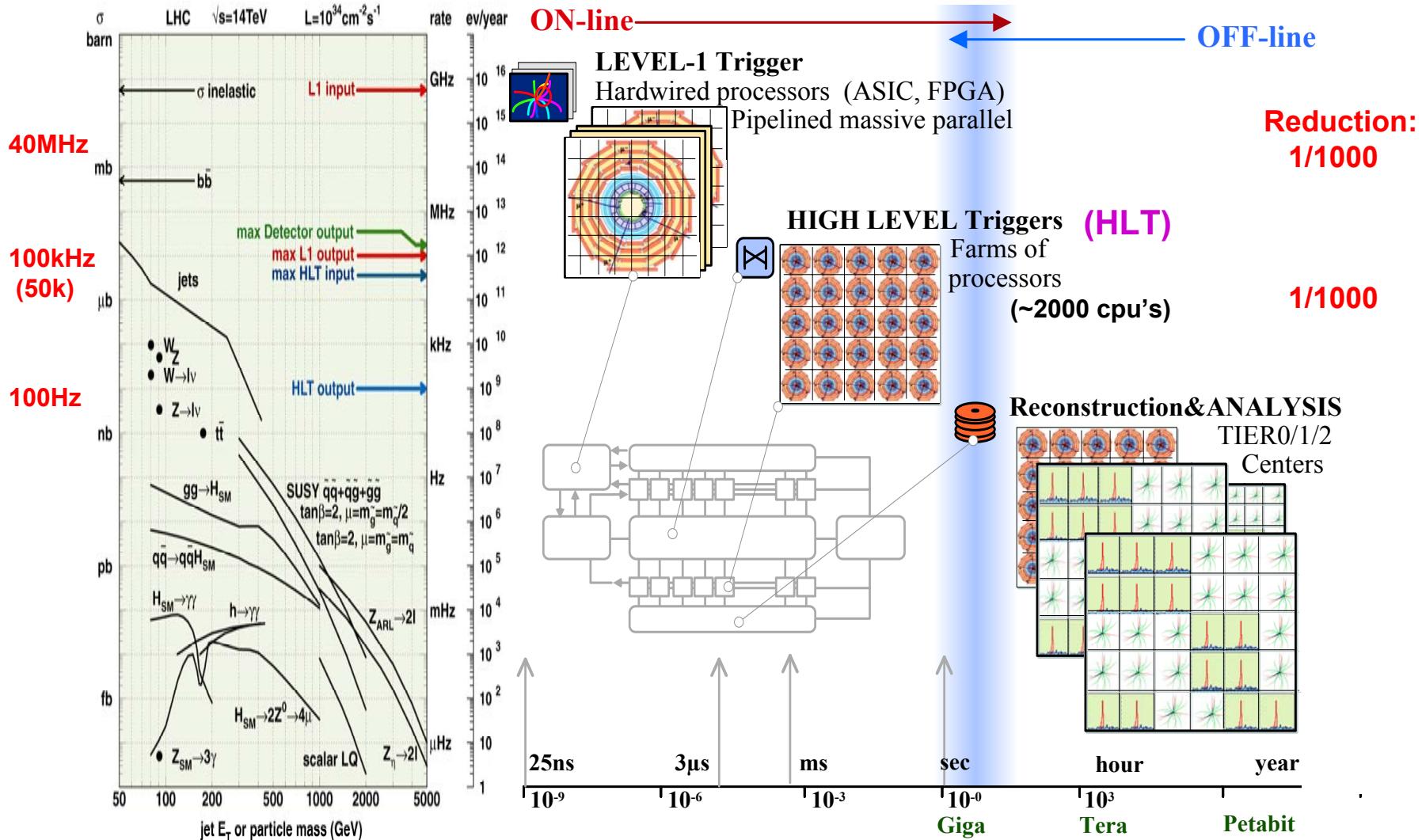
After all cuts



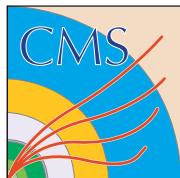
$$50 < M_T < 140 \text{ GeV}$$



# Physics Selection



We plan to use HLT farm to select calibration events and minimize the data volume.

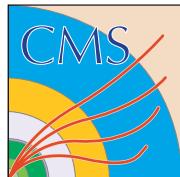


# L1 for Low Luminosity

$2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

Trigger	Threshold (GeV or GeV/c)	Rate (kHz)	Cumulative Rate (kHz)
Isolated e/ $\gamma$	29	3.3	3.3
Di-e/ $\gamma$	17	1.3	4.3
Isolated muon	14	2.7	7.0
Di-muon	3	0.9	7.9
Single tau-jet	86	2.2	10.1
Di-tau-jet	59	1.0	10.9
1-jet, 3-jet, 4-jet	177, 86, 70	3.0	12.5
Jet* $E_T^{\text{miss}}$	88*46	2.3	14.3
Electron*jet	21*45	0.8	15.1
Min-bias		0.9	16.0
<b>TOTAL</b>			<b>16.0</b>

A prototype L1 table for 50kHz system with x3 safety factor.



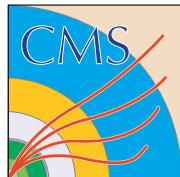
# HLT for Low Luminosity

## $2 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$

Results from full detector and trigger simulation – 7M events used in 2001-02.

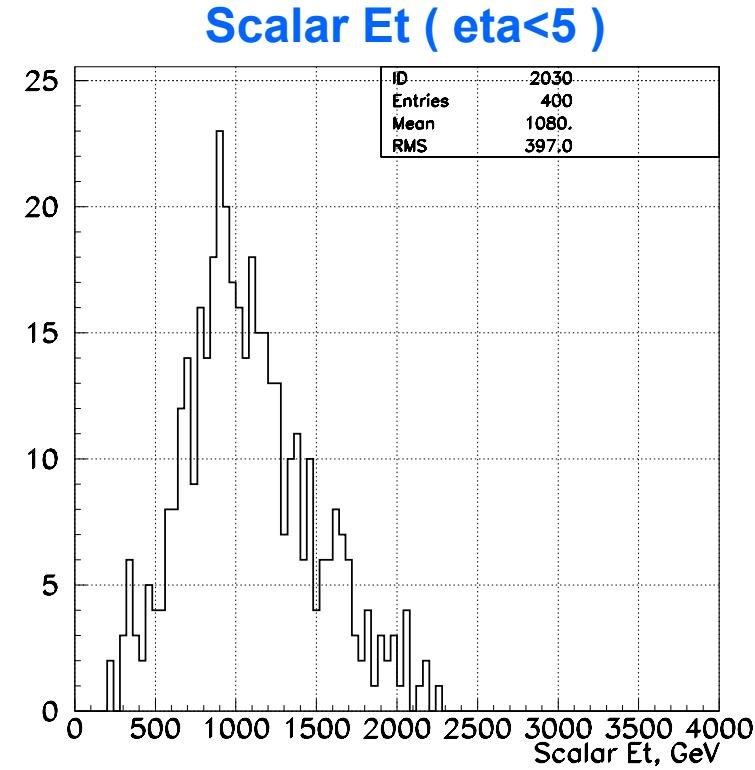
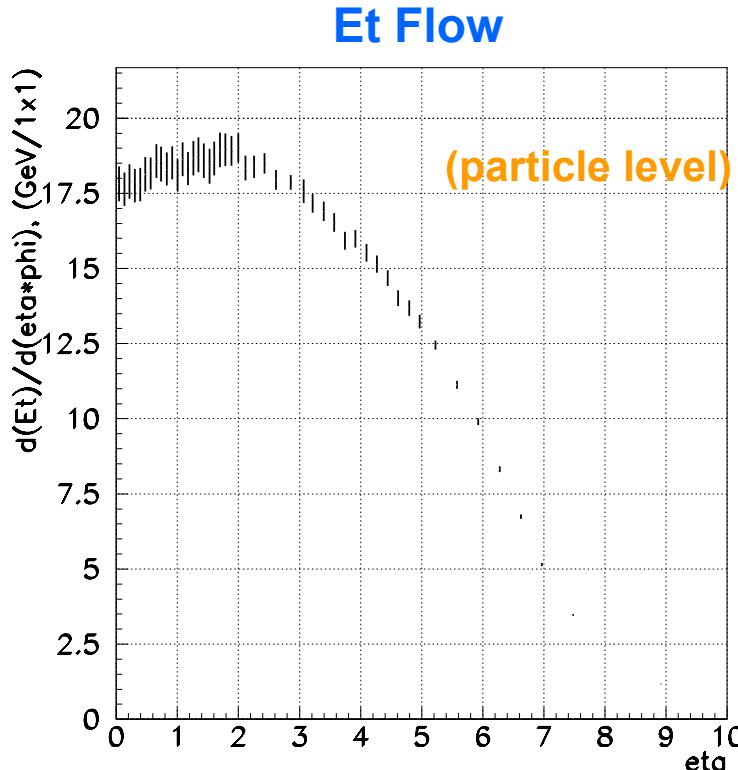
Trigger	Threshold (GeV or GeV/c)	Rate (Hz)	Cuml. rate (Hz)
Inclusive electron	29	33	33
Di-electron	17	1	34
Inclusive photon	80	4	38
Di-photon	40, 25	5	43
Inclusive muon	19	25	68
Di-muon	7	4	72
Inclusive tau-jet	86	3	75
Di-tau-jet	59	1	76
1-jet * $E_T^{\text{miss}}$	180 * 123	5	81
1-jet OR 3-jet OR 4-jet	657, 247, 113	9	89
Electron * jet	19 * 45	2	90
Inclusive b-jet	237	5	95
Calibration etc		10	105
<b>TOTAL</b>			<b>105</b>

CMS DAQ TDR, Dec. 2002 (CERN/LHCC 2002-26)



# Minimum Bias Events (in-time pile-up)

X-sec = 55mb >>> 17.3 min-bias/crossing at 10E34

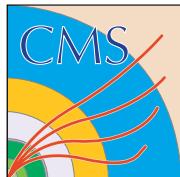


~17 GeV in unit ( $\eta \times \phi$ ) !

( equiv. cone radius 0.56 )

$\langle \text{Scalar Et} \rangle = 1080 \text{ GeV}$

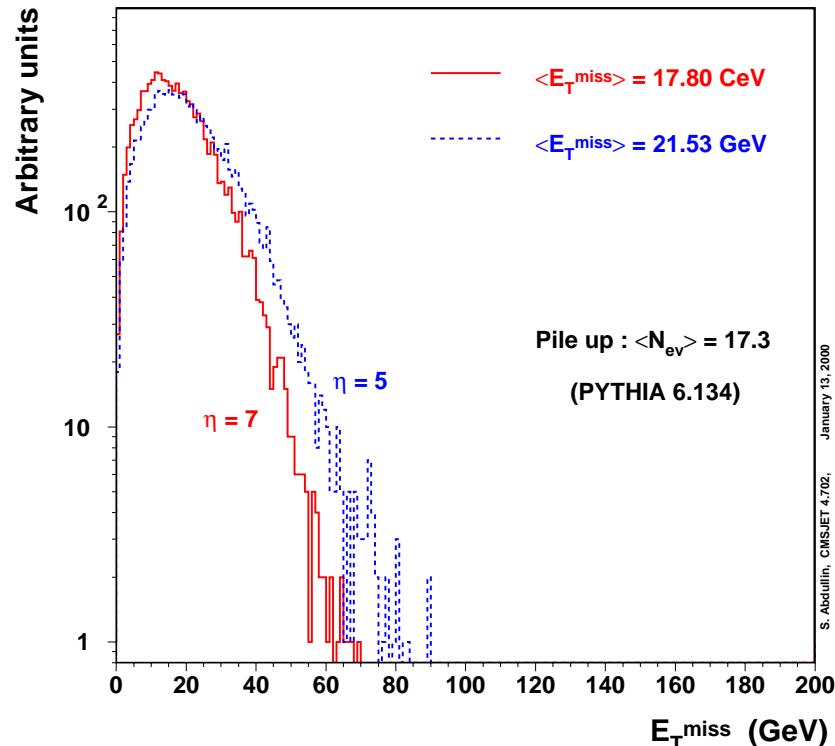
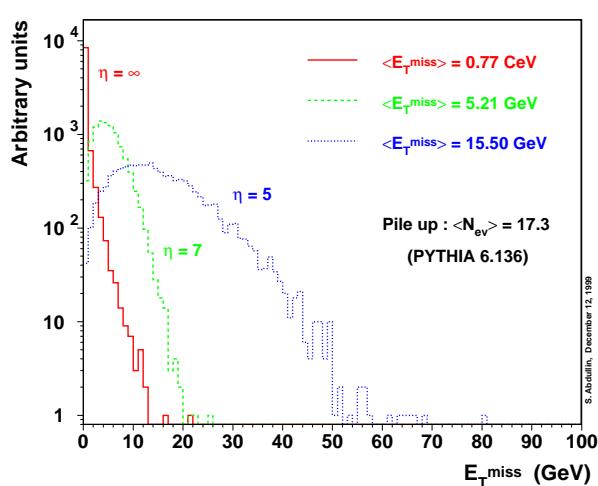
Note:  $\langle \text{Scalar Et} \rangle = 750 \text{ GeV}$  for ttH



# MET with Pile-up (eta 5 vs 7)

CMSJET – parametrized simulation

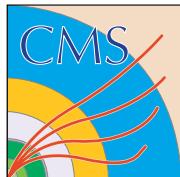
Particle level  $E_T^{\text{miss}}$  calculation for various  $\eta$  coverage



	gen.	cmsjet
eta	res.	all(*)
5	15.49	19.36
7	5.21	12.92
(all = res. & B-field & vtx smearing)		

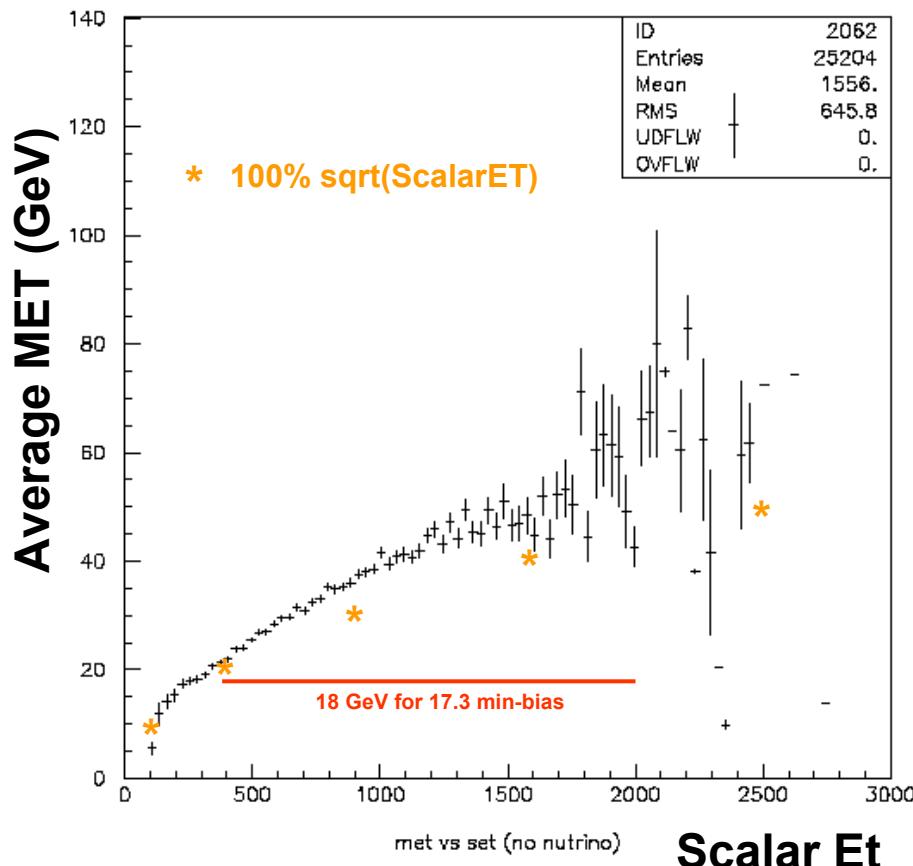


~ Equal contribution from  
eta 5-7, resolution and B-field  
(15GeV)      (12GeV)      (9-12GeV)



# MET Resolution

QCD Jets with no neutrino/muon  
(no pile-up)



$$Ex = \sum (\text{Ex-tower})$$
$$Ey = \sum (\text{Ey-tower})$$

Any way to improve this?

e.g.

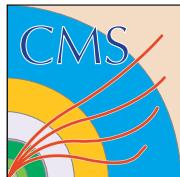
$$Ex' = Ex + \sum (\Delta(\text{Ex-jet}))$$
$$Ey' = Ey + \sum (\Delta(\text{Ey-jet}))$$

Improvement is shown in  
Higgs mass reconstruction  
in  $qqH \rightarrow \tau\tau$

Using reconstructed  
Charged tracks?



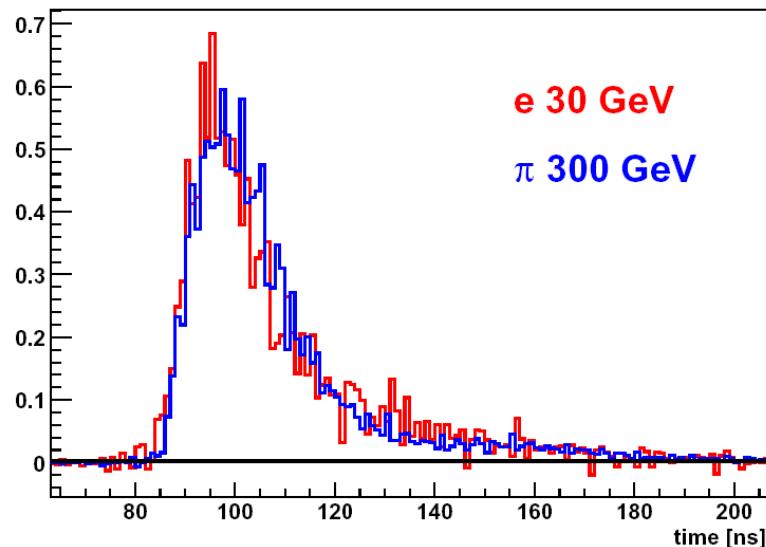
# HF Calibration



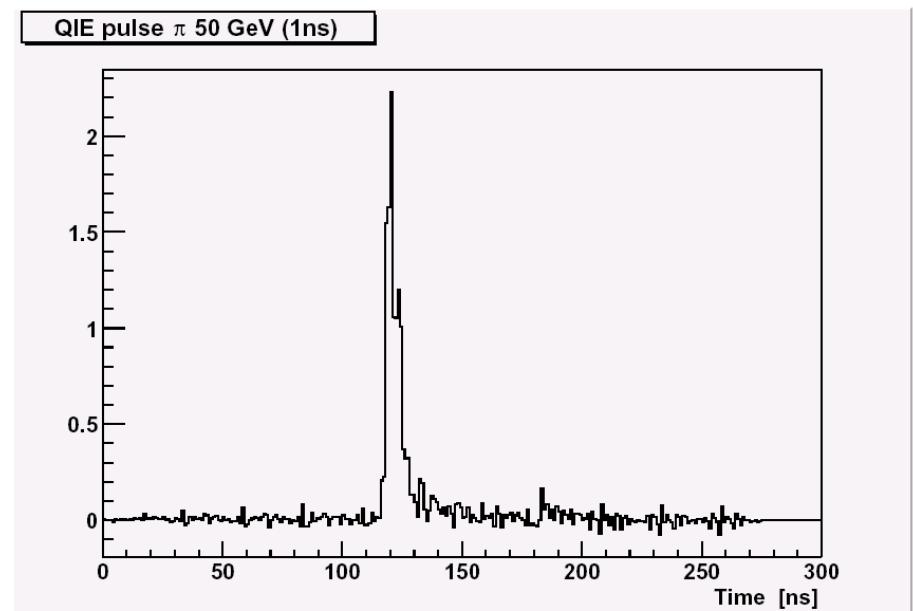
# HB/HE signal

(TB2003)

HB



HF



HF signal is very fast.  
→ all signal in 25ns time slice.

~15 p.e./GeV

0.25 p.e./GeV in E  
2.5-19 p.e./GeV in ET



# HF calibration

**TB2003/TB2004**

**Beam / Wire Source**

**Measure amplitude and rate of single p.e.**

**wire source: low rate → Challenge to get good accuracy.**

**In-situ (Plan)**

**minimum bias**

**QCD jets**

**photon-jet balance**

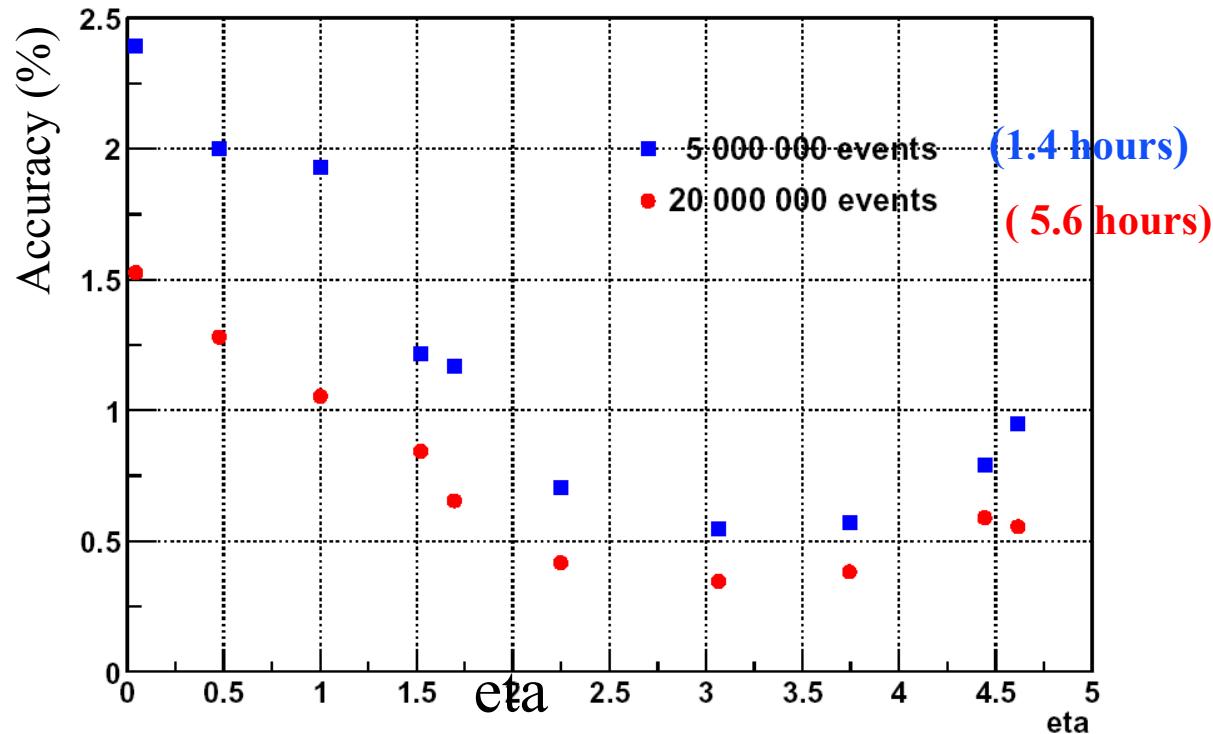
**Z-jet balance**

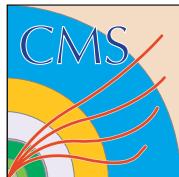
- HF cannot use reconstructed charged tracks, like in HB and HE.
- Need to monitor radiation damage.



# $\Phi$ -symmetry calibration with min-bias events

Process min-bias events in the HLT farm at 1kHz  
and send “histograms” to tape.

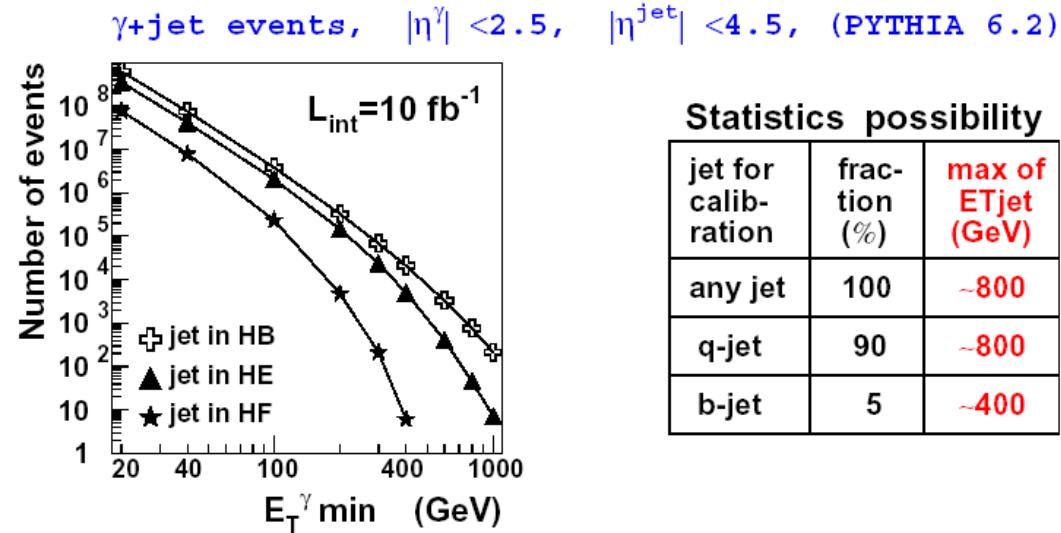
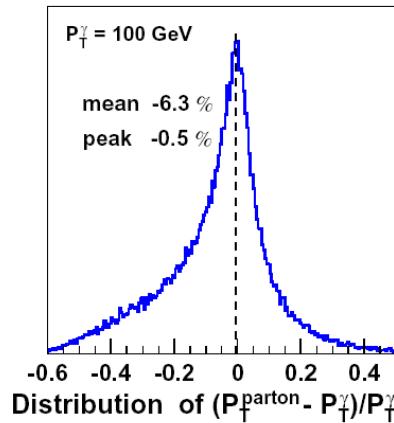




# In-situ Calibration (II)

## $\gamma + j / Z + j$

### $\gamma + \text{jet } E_T$ balance

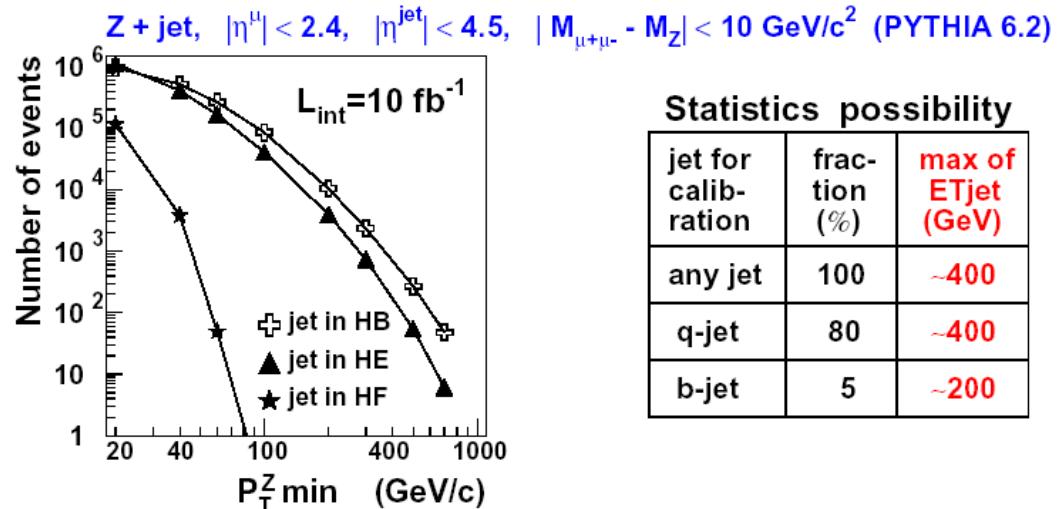


### Statistics possibility

jet for calibration	frac-tion (%)	max of ETjet (GeV)
any jet	100	~800
q-jet	90	~800
b-jet	5	~400

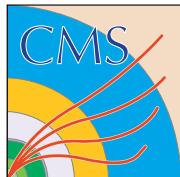
### $Z + \text{jet } E_T$ balance

Lower rate than  $\gamma+j$ ,  
but less background.



### Statistics possibility

jet for calibration	frac-tion (%)	max of ETjet (GeV)
any jet	100	~400
q-jet	80	~400
b-jet	5	~200



# HLT for calibration: $\gamma + \text{jet}$

Several processes will be used for calibration of jet energy. Among those considered so far (e.g. Z+jet, ttbar etc.), only  $\gamma + \text{j}$  requires a dedicated HLT.

## $\gamma + \text{jet}$ trigger

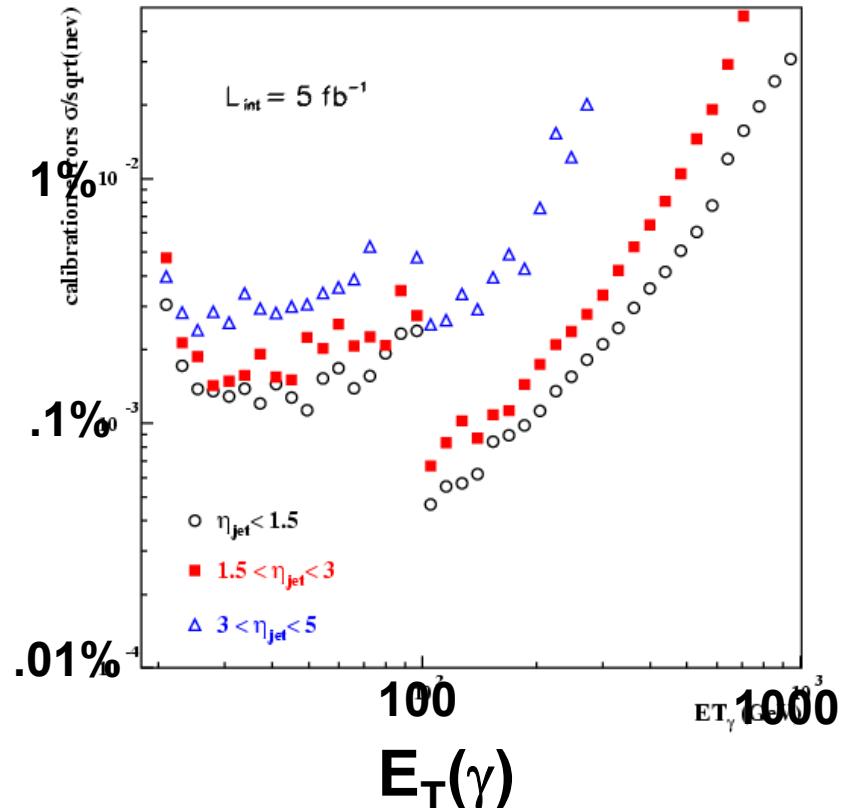
For  $\text{ET} > 80\text{GeV}$ :

- HLT single photon

For  $\text{ET} < 80\text{GeV}$

- L1 e/gamma ( $\text{ET} > 23\text{GeV}$ )
- very tight  $\gamma$  isolation  
with pixel and ECAL
- pre-scale

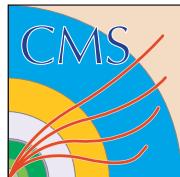
Statistical error after 3mo.  
running with 1Hz at 2E33



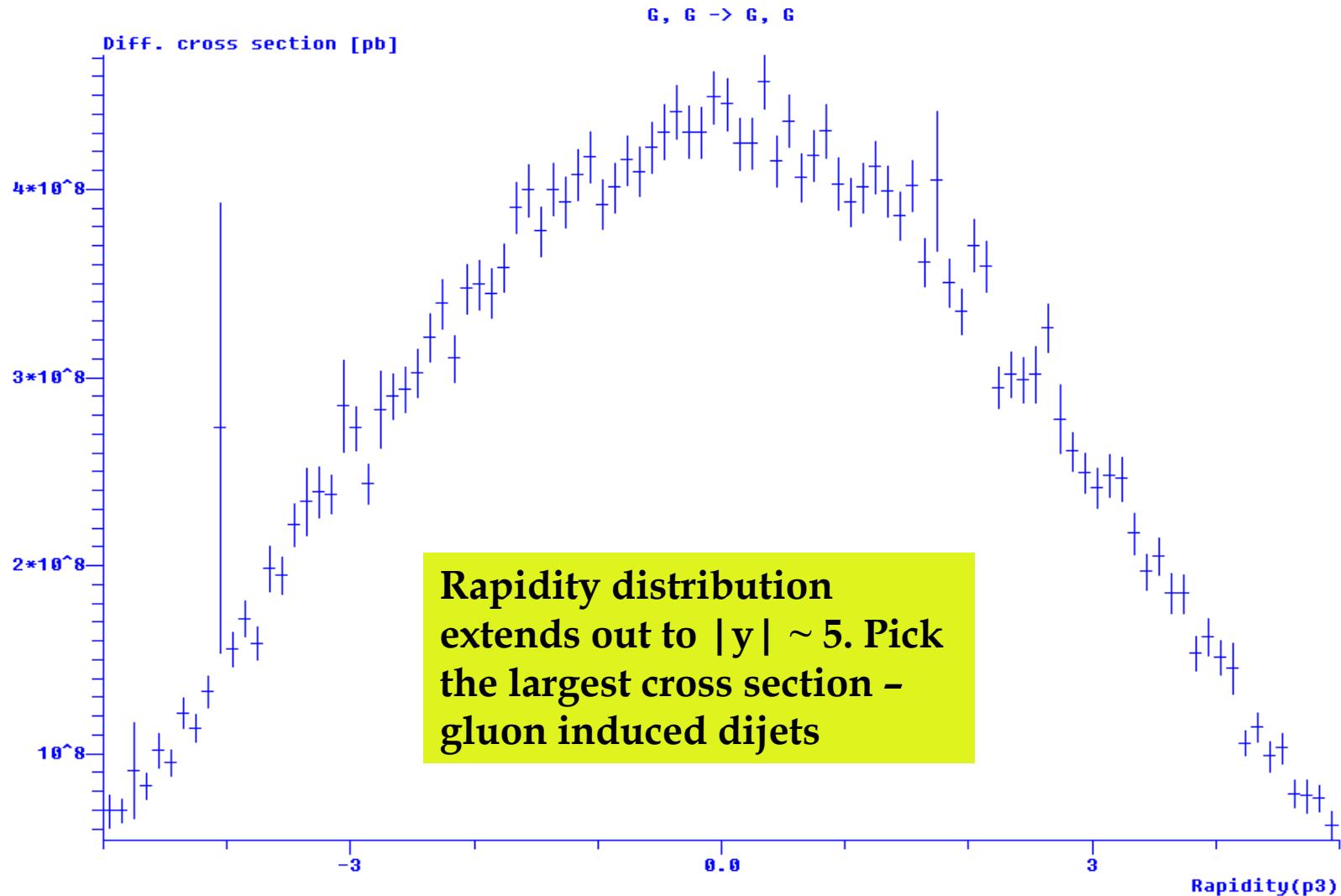


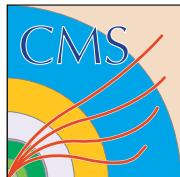
## Dynamic Range

0 - 3TeV ?

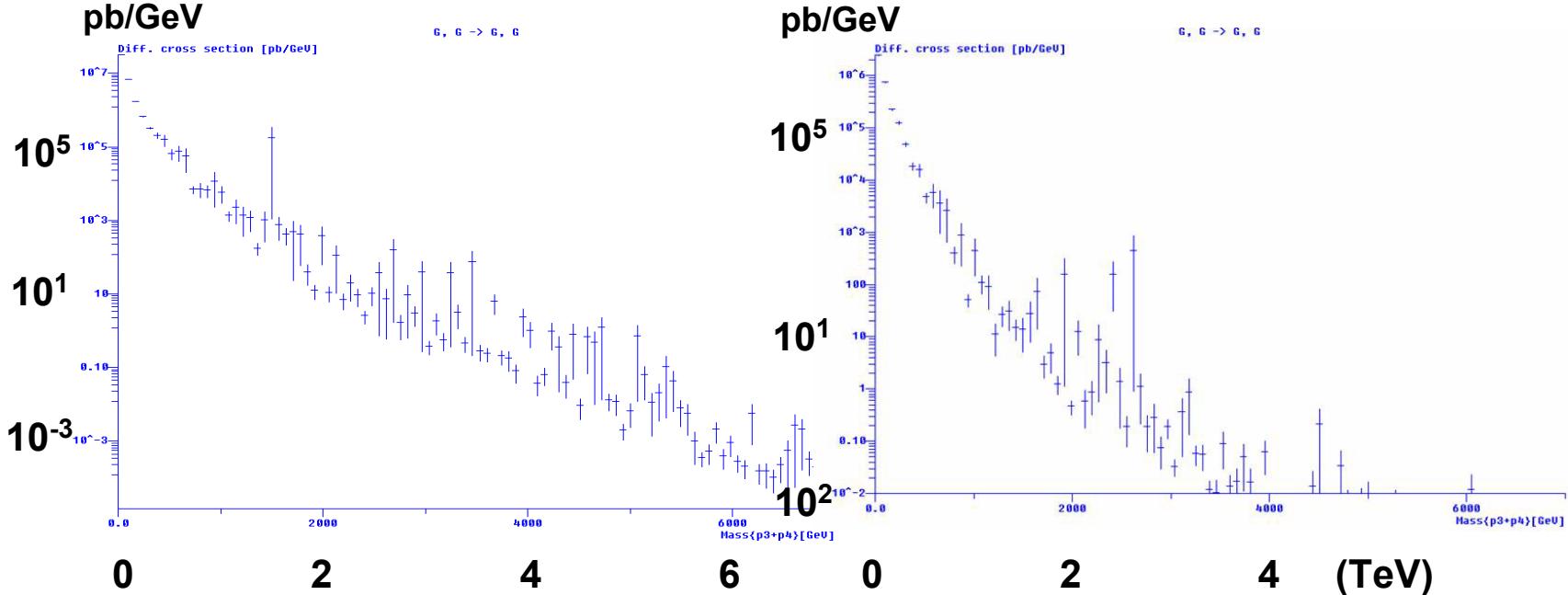


# Dijets at the LHC



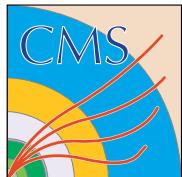


# Mass Distribution

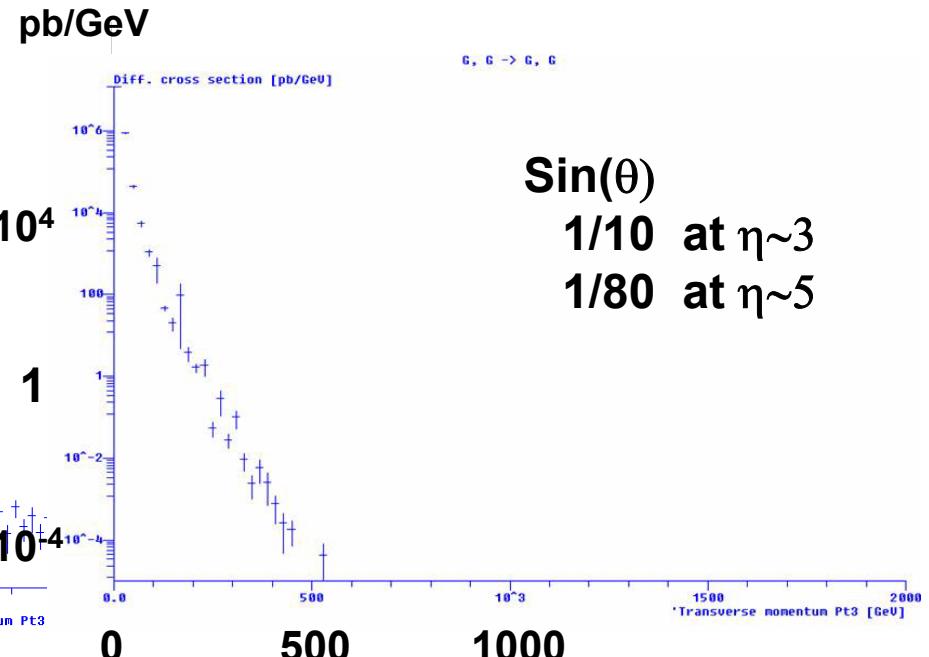
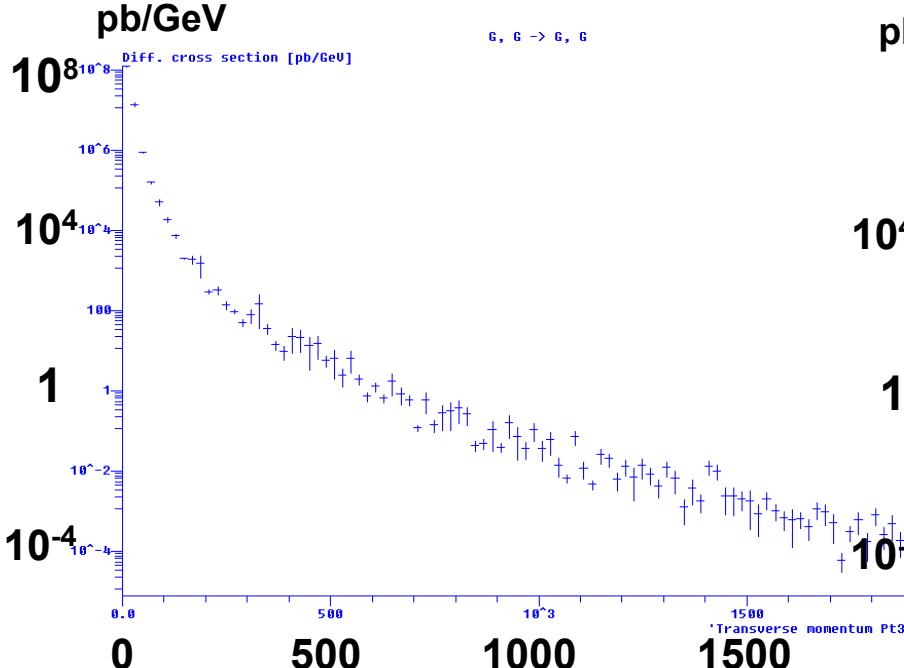


The dijet mass extends to large values. LHS is for all rapidity. RHS is for  $3 < y_3 < 5$ . The RHS jet mass distribution is somewhat “softer” than the inclusive distribution due to kinematic constraints. Clearly, TeV mass scales will be available at fairly low luminosity.

(Dan Green)

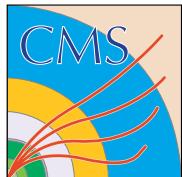


# Jet Pt and y

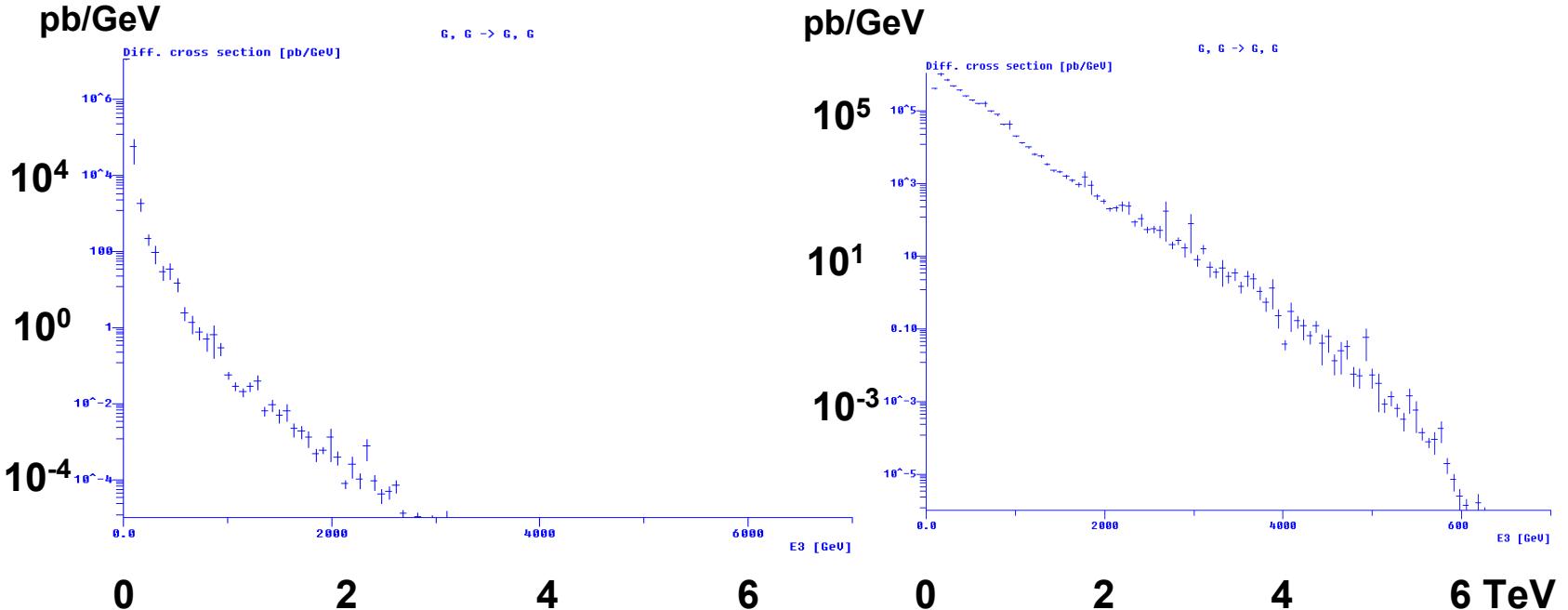


$$\begin{aligned} \sin(\theta) & \\ 1/10 & \text{ at } \eta \sim 3 \\ 1/80 & \text{ at } \eta \sim 5 \end{aligned}$$

The LHS is for inclusive jets. The RHS has a jet in the HF rapidity range and plots the Pt of that jet. Note the steep falloff for the HF region. Note also that the highest Pt, and thus the shortest distance, is accessible to the barrel but not the HF. Therefore studies of compositeness and excited quarks will populate the HB and not the HF.



# Energy and $y$



The LHS is for  $|y| < 1$  while the RHS is for HF. The E plot is  $\sim$  the Pt plot for HB. Clearly, while HB allows a study of the highest Pt, HF has jets with the highest energy. They are, however, limited to Pt of  $< 500$  GeV, while HB goes to  $< 2000$  GeV with the same cross section. A factor of 2 in E is a factor of 10,000 in rate.



# Observations (Dan Green)

- The HF will saturate sometimes unless 7000 GeV is below saturation.
- There is an energy continuum in HF, so any conclusion is “soft”.
- The highest Pt (shortest distance) Physics is in HB.
- Therefore, if we allow saturation it will have a rate for dijets. What do we do? Throw out the events? They have  $Pt < 500$  GeV for the jets and this kinematic region is covered in other detectors (HE, HB).